A Brief Literature Review of the Status of Early Stand Density Management in other Forest Industrialized Countries

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Problem:

One of the most complex decisions faced by forest managers involves determining the optimal stand densities at given points in time to reach specific end-product objectives (Teeter and Caulfield, 1991). They noted that one goal of forest management is to manipulate stand density in such a way as to maximize stand value, but also pointed out that a simple understanding of biological processes was not enough since per-tree values change as trees grow and become capable of yielding higher valued products.

Briggs and Fight (1992) noted that research on the effects of silvicultural activities on wood properties, product values, and processing and harvesting costs has lagged behind research on growth and yield, stocking control and fertilization. Stand density decisions are made more difficult because foresters still lack basic information linking tree growth to product value.

Cole and Koch (1995) pointed out that early actions to reduce stocking increase stem taper and branch size in the remaining trees. The problem is, can we carry out stand density management in second growth lodgepole pine stands and still maintain or enhance the wood quality and value currently realized from harvesting old-growth stands?

Cole and Koch (1995) further pointed out that stocking control and thinning are expensive. The costs discourage managers from thinning lodgepole pine stands unless they can offset the costs by selling trees cut during the thinning (Koch and Barger, 1988).

On commercial forest lands, many silviculturists, wildlife managers, and watershed managers would agree that the cost of juvenile stocking control should be paid by income from the previous harvest. Or is it part of the regeneration cost. The cost of pre-commercial thinning is the financial "bone in the throat" for forest managers (Cole and Koch, 1995).

In British Columbia it is more a matter of "who pays?" for the spacing that is of prime importance, not the cost of spacing. We must also educate operational foresters in the province that stand level financial analysis is only one part of the decision whether or not to space a stand. There are many other benefits from early stand density control, the benefits from which cannot be easily quantified like forest products.

There are three important considerations to keep in mind when contemplating early stand density management;

- Why do other forest industrialized countries invest in early stand density management?
- How do they rationalize their stand level investments in early density control?
- At most we carry out silvicultural activities on less than 20% of all the hectares harvested annually in the province. Early stand density management provides diversity and increased flexibility to manage our forests for a myriad of resource objectives.

Why early stand density management?

hinning is carried out to reduce stand density and in so doing to reduce competition; the remaining trees have more space to grow and put on more increment. It is normally done to provide the owner with some revenue, though if this is not possible, as with some early thinnings, it is carried out with the expectations of greater returns later in the rotation (Saville and Evans, 1986). According to Day (1997), where man-

made forests are being established, thinnings often provide the only yield and revenue before the end of the first rotation. These thinnings depend on adequate stocking and early stand density control. This was evidenced by visits to Argentina, Chile, Ghana, Zimbabwe, Australia and New Zealand (Day, 1997).

Germany: Safeguarding the sustainability and restoration of forests were of prime importance at the end of the 18th century in Germany, when forests were devastated and the need even for small-sized timber was very high (Kladtke and Kenk, 1997). Later, on, favourable price/cost relationships and a continuous demand for timber lead to strategies to maximize the volume increment and thus the volume production, of stands. Light thinnings to maintain high "critical basal area per hectare" became the entrenched philosophy in Germany. Today, due to increasing costs and decreasing prices for small wood, and the increased risk of snow and wind breakage in higher density stands, Germany's philosophy has changed from maximizing volume production with maximizing the value production in stands and minimizing risks.

Udo Sauter (1999 personal communication) confirmed the new regimes in Germany. All species are spaced to around 1000-1500 sph. 100% of all Douglas-fir and 60% of all spruce are also pruned.

For Norway spruce, the number of trees planted per hectare has been lowered from 10,000 trees after World War II to 1000-1500 today (Kladtke and Kenk, 1997; Weise and Kublin, 1997). In naturally regenerated stands or plantations with higher tree numbers, the tree number has to be reduced schematically to 1000-1500 per hectare at 2m top height. Weise and Kublin (1997) further reported that with planting tree numbers upwards of 3000 sph, the estimated surplus would only exceed the current stand's total value by about 10% at 100 years.

Strutt (1991) concluded from an economic point of view that it is foolish (since too dangerous) to improve wood quality by high stand densities.

Demands for slowly grown timber with narrow tree rings can be covered only by timber from lower site classes. Branchiness of the crop trees can be limited only by green pruning, not by high stand densities.

Kladtke and Kenk (1997) summarized the overall gross volume loss due to stand density management well by stating "Volume production losses are unimportant and minor compared to the positive effects on stability, economics and even ecology, because low stand densities offer better chances for mixtures, higher biodiversity, improved nutrient cycles and water regime and less acidification".

Finland: Hallman (1997) thinnings to generate revenue is an integral part of Finland's economy. "Wood removed in thinnings appreciably increases not only the amount of wood to be cut at present, but also the economic returns. If thinning is not carried out, competition between trees for growing space will gradually result in crop losses owing to natural mortality". Another objective Finland has for thinning is to promote the development of the stand left on the thinned area and thus increase the value of the stand in subsequent cuttings. "In other words, thinning is an investment in future opportunities for cutting. Especially in the first cutting, this silvicultural perspective is one of the main considerations.

Thinning increases space for growth and allows the trees in the stand to grow sturdy more quickly. Thinning also improves the quality of the subsequent tree crop. Likewise, it has a positive impact on the state of health of the stand."

In order to carry out the first commercial thinning entry into Scots pine stands in Finland the general practice is to space sapling stage stands to a density of around 2000 stems per hectare. "Sapling stand management is an important work stage from the standpoint of the entire silvicultural chain. The density of the sapling stand primarily affects the increase in size of the trees and thus the harvesting conditions and costs of first cutting.

In many studies it has been concluded that in Finland's conditions approximately 2000 stems per hectare is a good compromise. It ensures a reasonable increase in stem size up to the first cut, while not leading to any appreciable losses in yield. In sapling stand thinning, the target growing stock density varies in

practice between 1600-2500 stems per hectare according to the tree species and growing site" (Hallman, 1997). He further states that "Of course, the density during the sapling stand phase greatly influences the development of tree quality. In a dense sapling stand the increase of the thickness of branches slows down and self-pruning accelerates. This fact is nowadays taken into consideration in silviculture by not thinning young Scots pine and birch plantations until they are 3-6 meters high."

Sweden: In Sweden the common practice is to plant sufficient stock (2500 sph) to ensure enough trees are on site when the pre-commercial thinning is undertaken. The first pre-commercial thinning reduces the stocking on site to about 1,500 – 2,000 sph. This ensures roughly 1,500 sph at the time of first commercial thinning (at approximately 13m tree height) where the stand density if further reduced from 1,500 sph to 960 sph (Elfving, 1997).

United States – Inland Empire: In the Inland Empire of the United States, Ballard and Long's (1988) paper clearly outlined the relationship between stand density, competition and log quality. The rate of crown recession is strongly influenced by stand density. Log quality characteristics that may be influenced by the rate of live-crown recession include branch size, stem taper, wood density, and the proportion of sapwood and juvenile wood. In a detailed study they concluded that pre-commercial thinning should be delayed until after the base of the live crown has receded above the top of the first log. This means that the before-thinning stand density should be roughly 2000 sph.

Koch (1996) summarized many published research papers in the western United States, British Columbia and Alberta into a 3-part compendium on the Management of Lodgepole Pine. Many studies provided a key insight into stocking density and post-spacing stand density. These studies include:

- Alexander (1986) reported that stocking densities of as much as 3000 seedlings/ha surviving 4-5 years after initial regeneration effort may be desirable.
- (Cole 1975; Johnstone 1983) If trees are well distributed, however, stocking should not exceed 1,240 to 1,980 stems/ha between 5 and 20 years of age.
- Lotan and Critchfield (1990) suggest that uniform distribution and full utilization of the site may require establishment of 2,470 stems/ha and thinning to obtain proper spacing and to achieve significant genetic gains from selection of elite trees when thinning.
- (Lotan and Perry 1983) As a general prescription for average sites, spacing should be about 2.4 by 2.4 meters, giving about 1700 sph.
- Ferdinand (1983) For Alberta, he recommends 1,250 – 1,600 plantable spots per hectare.
- Johnstone and Pollack (1990) For British Columbia they recommend a planting density of at least 1,600 stems/ha.

British Columbia: Since the advent of the Lodgepole Pine Task Force (Middleton et. al. 1995), the post-spacing densities recommended to maintain wood quality and stand merchantable volume are roughly 1,600 – 2,000 sph. At these post spacing densities branch size, juvenile wood and stem taper are not an issue. When targeting early stand operability and filling age class gaps in order to maintain timber supply, spacing densities from 1200 –1600 sph are recommended. Post spacing stand densities less than 1200 sph are only recommended if all remaining crop trees are pruned to produce high valued clear wood. The recommended timing of spacing lodgepole pine is when the crop trees are roughly 4 meters in height.

In high density naturally regenerated stands more than one thinning may be necessary. A first thinning at 0.5 – 1.5 m crop tree height may be necessary to prevent height repression. The recommended leave density for this spacing would be 3-5000 sph. The second thinning could then be timed for 4 m crop tree height with the post spacing densities being 1600-2000 sph.

On certain sites where forest health concerns warrant caution, delaying spacing or leaving 100-200 extra stems per hectare will ensure adequate stems to prevent voids due to pest losses.

Dr. Wayne Johnstone has established several espacement and spacing trials in lodgepole pine around the province. These trials now have 13-15 years of measurements. Even at these young ages the results to-

date clearly demonstrate that in the 1,500 sph and 2,000 sph plots that the tree crowns are closing in and starting to lift. These trials demonstrate that the post-spacing density range of 1,600 – 2,000 sph will ensure second growth stands of lodgepole pine will have comparable wood quality characteristics (branch size, taper, juvenile core, etc) to currently harvested unmanaged, old-growth stands. Documentation of other espacement and spacing trials around the province should be undertaken to confirm the findings of the espacement trial in Cranbrook.

The Impact of Stand Density on Merchantable Volume and Piece Size

Figure 1 below was taken from the Lodgepole Pine espacement trial near Penticton, B.C. Figure 1(a) demonstrates the fringe between the 2000 sph espacement (left) and the natural surrounding stand (>10,000 sph). At the same age (15 years) the stand at 2000 sph is almost twice as tall as the surrounding unmanaged stand. Crowns in the 2000 sph stand are starting to lift. The lower branches are dying and have small branch diameters that would not negatively impact wood quality and subsequent grade.

Figure 1(b) is a straight on view of the edge of the dense natural stand. These trees will continue to undergo intense inter-tree competition over the next 15-20 years. This inter-tree competition will result in widening the merchantable volume and piece size gap between these two stands.

Figure 1(a) Figure 1(b)

Rotherham and Mooney (1988) conducted a study comparing the difference in average piece size of logs going through a mill. For one mill shift logs of roughly 19 cm were run through the mill. The second mill shift (same shift length as the first set of logs) logs were roughly 24 cm butt log diameter. Table 1 below summarizes the results. The increase in average log size by only 5 cm meant that 28 % more lumber was produced from the same number of logs in the same length of time. Lumber recovery factor (the amount of wood extracted from 1 cubic meter of wood) increased by 6%. Rotherham and Mooney (1988) concluded that foresters should grow larger rather than smaller trees because tree size is far and away the most important factor to both the logger and the sawmill. They suggested that regardless of equipment type, total harvesting costs fall rapidly with an increase in tree size, that product price is the most important variable for any sawmill, and the value of larger dimension lumber is an important factor which depends on log quality and size. They added that the lumber recovery factor (LRF) is the second most important variable to the sawmill, and that LRF increases as the diameter of the log mix increases.

Table 1: Rotherham and Mooney Sawmill Productivity Study (1988)

Sawmill Productivity			
	Sawmill A	Sawmill B	Increase
Log mix	6–13 in. (15–33 cm)	6–22 in. (15–56 cm)	
Average log diameter	7.5 in. (19.0 cm)	9.4 in. (24.0 cm)	
Volume consumed (MCCF)	76	90	
Output (Mfbm)	51.5	65.7	28%
Lumber recovery factor	6.8	7.2	6%

Summary

There is significant operational information from around the world demonstrating the benefits of early stand density management. Research trials in British Columbia are only beginning to provide data demonstrating the benefits of early stand density management. Simulation models that do not have sufficient growth and yield information (60-80 years) can provide only crude estimates of merchantable volume, piece size and distribution of piece size by diameter class at any predetermined rotation. Financial analyses based on output from these models is at best questionable.

Dr. Zhang (2000) demonstrated the benefits from early stand density management by looking at the costs and benefits from stand establishment right through to harvest, transporting, milling and grading the final product. His study in Jack Pine in eastern Canada concluded that spacing indeed does pay at 4% Return On Investment (ROI). Not only did the stand make a decent rate of return at harvest, it employed workers in the planting, tending, harvesting, transporting and milling stages of producing products from our forest industry. More studies like these are needed to determine the actual benefits and costs of early stand density management.

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